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GB 2050567 A GB 1446159 A GB 0725687 A
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(54) Abstract Title
Torque transmitting devices

(57) In a ball constant-velocity joint of the fixed or plunging type the ball tracks are of hybrid form in a transverse plane having a root portion 54-55 of a lower numerical conformity (defined as the radius of the track cross-section in the transverse plane to the radius of the ball) and flank portions 54-56 and 55-57 of a higher numerical conformity. Such ball tracks could also be used in other torque-transmitting devices using balls and tracks to transmit torque.

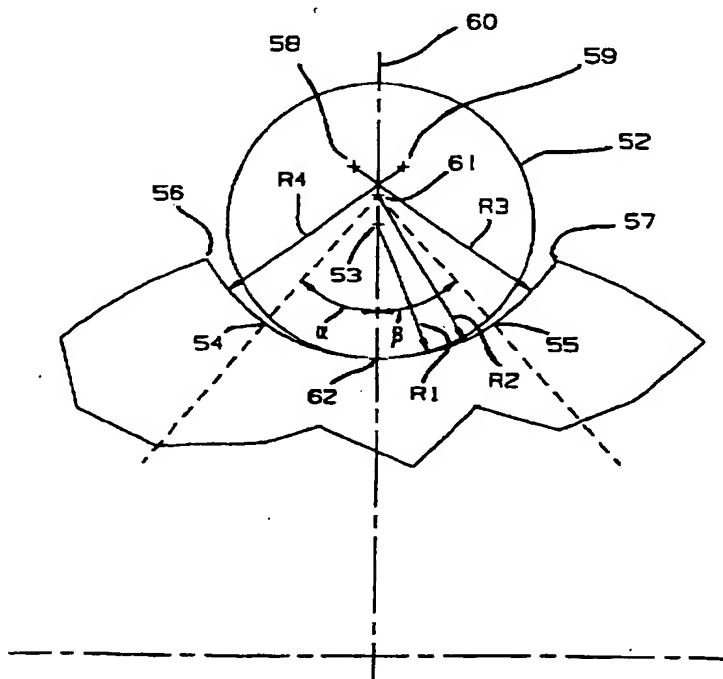


FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 331 570 A

Title: TORQUE-TRANSMITTING DEVICES

This invention relates broadly to torque-transmitting devices of the kind which comprises: a first member having a rotational axis and a plurality of tracks; a second member disposed in co-operative relationship with the first member and having a rotational axis, the second member being provided with a plurality of tracks which face the tracks in the first member in opposed pairs; and a plurality of balls disposed one in each pair of facing tracks in the first and second members for torque transmission between the members such that on rotation of one of the members torque is transmitted to the other member via the balls.

Such a torque-transmitting device will hereinafter be referred to as "a device of the kind specified".

More specifically the invention relates to ball-type constant-velocity-ratio universal joints, of the kind which comprises: an outer joint member of hollow configuration, having a rotational axis and in its interior a plurality of tracks circumferentially spaced about said axis; an inner joint member disposed within the outer joint member and having a rotational axis, the inner joint member being provided on its exterior with a plurality of tracks circumferentially spaced about its rotational axis and which face the tracks in the outer joint member in opposed pairs; a plurality of balls disposed one in each pair of facing tracks in the outer and inner joint members for torque transmission between the members; and a cage of annular configuration disposed between the joint members and having openings in which respective balls are received so that their centres lie in a common plane; the configuration of the tracks in the outer and inner joint members, and/or the internal and external surfaces of the cage, being such that when the joint is articulated the plane containing the centres of the balls (the bisector plane) is caused substantially to bisect the angle between the rotational axes of the joint members.

Such a joint will hereinafter be referred to as "a joint of the kind specified".

There are several types of joint of the kind specified, differing from one another, inter alia, in respect of the arrangement and configuration of the tracks in the joint members and/or of the internal and external surfaces of the cage whereby the bisector plane is guided as aforesaid

thereby giving the joint constant-velocity-ratio operating characteristics.

The invention is applicable to fixed, non-plunging joints and to ball-type plunging joints of the double-offset and cross-groove types.

More particularly the invention is concerned with the form of the ball tracks in devices and joints of the kind specified.

In joints of the kind specified there are three main forms of ball track. The first form is a round track in which the track form is a circular arc when viewed in cross-section in a transverse plane perpendicular to the longitudinal plane of symmetry of the track and containing a line which is normal to the vertex line of the track which lies in the longitudinal plane of symmetry. The longitudinal plane of symmetry is a plane extending along the length of the track so that the track is symmetrical about the plane. Such a transverse plane will hereinafter be referred to as "the transverse plane". The second and third track forms are an elliptical track in which the track form is the arc of an ellipse centred about the end of its major axis, and a Gothic arch track in which the sides of the track are formed by circular arcs struck about centres which are offset on opposite sides of the longitudinal plane of symmetry of the track, in each case when viewed in the transverse plane.

When a joint of the kind specified transmits torque, the balls make contact with the track at a position spaced from the root of the track at a contact angle which is the angle in the transverse plane between the longitudinal plane of symmetry of the track and a line containing the centre of the contact area between the ball and the track and the ball centre.

Hereinafter we use the term "numerical conformity" to define the track form and this value is the radius of the track cross section in the transverse plane divided by the radius of the ball.

In a joint of the kind specified with a round track having low numerical conformity, e.g. 1.002, under torque the stress on the track as the ball moves to its contact angle is such that there is a low stress at the contact angle and a high stress at the track edge. The pressure distribution is such that breakdown may occur at the track edge before breakdown occurs at the contact angle.

With a Gothic arch track the numerical conformity chosen is usually high and thus the stress on the track surface is high at the contact angle but the stress is distributed over a relatively small area and high stress at the track edge is avoided. There is a similar stress distribution on an

elliptical track if, as is usual, it has a high numerical conformity.

If the numerical conformity of a round track is increased to e.g. 1.02 then there is a better stress distribution as high stress at the track edge is substantially avoided assuming that the ball radial lash (as hereinafter defined) in the joint is not excessive. However by increasing the numerical conformity of a round track there is an increase in rotational backlash as compared with a joint having an elliptical or Gothic arch track with a similar numerical conformity because, as described below, the contact angle with the latter shapes of track has a minimum value of about 40°.

The object of the invention is to provide a device or joint of the kind specified with a track form which both avoids high stress at the track edge and minimises the stress around the contact angle but which has an acceptable rotational backlash.

According to the invention we provide a device or joint of the kind specified having a hybrid track form in the transverse plane with a lower numerical conformity at the root of the track and with the flanks of the track having a higher numerical conformity.

More specifically the invention provides a joint of the kind specified in which in at least one of the inner and outer joint members the tracks have, in cross-section in the transverse plane, a root portion formed as a circular arc with a relatively lower numerical conformity and flank portions on either side of the root portion and extending to or towards the edges of the track and which have a relatively higher numerical conformity.

The track form in the other joint member may be of the hybrid form set out above or may be of any other compatible form.

The advantages of the invention are that:-

1. There is a good distribution of stress on the track surfaces, with the stress at the track edge being no greater than the stress at the contact angle.
2. Having a lower numerical conformity in the root portion there is a reduction in rotational backlash, as compared with a joint having a round track with a higher numerical conformity, but an acceptable stress distribution.
3. The higher numerical conformity in the flanks of the track reduces the sensitivity of the contact angle to ball radial lash in the flank portions of the track and this

avoids high contact angles which would give high stresses at the track edges. Ball radial lash is defined as the pitch circle diameter (PCD) of the tracks in the outer joint member minus the PCD of the tracks in the inner joint member divided by 2. In general, the bigger the ball radial lash the bigger is the contact angle although the torque transmitted by the joint also affects the contact angle.

The root portion of the track may subtend an angle of approximately 80° at the centre of the root radius, i.e. 40° on either side of the longitudinal plane of symmetry of the track. If this angle is decreased much below 80° then the rotational backlash is increased and if the angle is increased much above 80° the stress on the track moves too close to the track edges causing there an undesirably high stress. The angle subtended by the root at the centre of the root radius should be between 70° and 90° .

The root should preferably have a numerical conformity within the range of 1 to 1.02. A numerical conformity of 1.002 would reduce the rotational backlash while a conformity of 1.01 may give optimum endurance.

The flanks of the track may be formed by circular arcs struck from centres offset from the longitudinal plane of symmetry of the track and the higher numerical conformity of the flanks should be between 1.005 and 1.09 and preferably between 1.01 and 1.04. A particularly advantageous value is between 1.02 and 1.03.

The flank portions of the track could be formed by elliptical arcs and in this case the numerical conformity will vary along the flank but the average value should be as set out above.

With a joint having round tracks with low numerical conformity the contact angle is high even with very little ball radial lash. With the track form according to the invention the contact angle will increase to say 40° , i.e. to the edge of the root portion of the track and will remain close to that value.

Thus the invention enables an acceptable stress distribution on the tracks to be obtained avoiding unnecessarily high stresses both at the track edges and at the contact area while also avoiding excessive rotational backlash in the joint.

The invention will now be described in detail by way of example with reference to the accompanying drawings in which:-

Figure 1 is a cross-section through a fixed ball joint of the kind specified;

Figure 2 shows at A, B and C the different forms of track presently in use in joints of the kind specified;

Figure 3 shows the stress distribution for a round track and a Gothic arch track as shown in Figure 2; and

Figure 4 is a diagram illustrating the form of track embodying the invention.

Referring first to Figure 1, the joint there shown comprises an outer member 10, an inner member 11 and a cage 12. The outer member is formed with arcuate, inwardly facing tracks 13 and the inner member is formed with arcuate, outwardly facing tracks 14. The vertex lines of the tracks 13 and 14 are shown at 113 and 114 and in each case lies in the longitudinal plane of symmetry of the track.

The tracks 13 and 14 in the members are aligned in pairs. In each pair of tracks is received a ball 15 and the balls are received in windows 16 in the cage which hold the centres of the balls in the bisector plane. The cage has inner and outer generally spherical surfaces 17 and 18 which engage with lands between the tracks on the inner and outer members and guide the cage. In the unarticulated state of the joint the centres of the arcuate tracks 13, 14 are offset on opposite sides of the bisector plane of the joint which is indicated at 19.

The arrangement of the track centres is such that during articulation of the joint the bisector plane containing the centres of the balls bisects the angle between the rotational axes of the outer and inner members i.e. the axes about which they rotate when the joint is in its unarticulated state.

A splined shaft 20 is received in a bore in the inner joint member and the shaft and the outer member 10 are connected by a boot 21 which retains the grease in the joint.

Figure 2 shows the forms of track which are presently in use. Figure 2A shows part of the joint inner member 11 and the track 14a is formed by a circular arc in the transverse plane struck from a centre 22 on the longitudinal plane of symmetry 23 of the track. The radius of the circular form 24 of the track 14a is indicated at 25 and is greater than the radius of the ball 26. The numerical conformity of the track is the ratio between the radii 25 and 26.

It will be seen that in the position of rest the contact area between the ball and the track

is at the centre of the root of the track as indicated at 27. The centre of the root lies on the vertex line 114 as described above. When torque is transmitted the ball moves away from its central position and engages the track on the flank at a contact angle which is the angle between the longitudinal plane of symmetry 23 and, a line containing the centre of the contact area of the ball with the track and the centre of the ball.

Figure 2B shows part of the inner member 11 having a track 14b of elliptical form 29. The major axis of the ellipse is aligned with the longitudinal plane of symmetry 30 of the track and before torque is applied the ball 31 makes contact with the track at two areas 32 and 33 with a contact angle of about 40°. The vertex line 114 of the track is also indicated.

Figure 2C shows a Gothic arch track where the track is formed of two circular arcs 34 and 35 respectively which are struck from respective centres 36 and 37 offset from the longitudinal plane of symmetry 38 of the track. Before torque is applied the ball 39 has two-area contact with the track at 40 and 41 with a contact angle of about 40°. The vertex line is indicated at 114.

Figure 3 shows the stress distribution which occurs when a joint having a round track or a Gothic arch track as shown in Figures 2A and 2C respectively is transmitting different amounts of torque.

In Figure 3A the stress distribution for a round track is shown by the lines 42, 43 and 44 which show the stress distribution as an increasing amount of torque is transmitted. It will be seen that, at the highest torque represented by the line 44, the stress has a peak 45 adjacent the edge 46 of the track because of the low numerical conformity of the track.

Figure 3B indicates the stress distribution for a Gothic arch track by the lines 47, 48 and 49 for increasing amounts of torque transmitted. It will be seen that the highest stress 50 at the highest torque is well spaced from the edge 51 of the track. This is also the case for the lower transmitted torques.

Figure 4 shows the track form of the invention in the transverse plane. The ball in the track is indicated at 52 and has a radius R1 from its centre 53. The root of the track between the points 54 and 55 is circular in the transverse plane and has a radius R2 from the point 61, R2 is greater than R1. Preferably the numerical conformity of the root of the track is 1.002. That is to say that the radius R2 is $1.002 \times R1$.

The flanks of the track extend from the points 54 and 55 to the track edges 56 and 57. The flank between the point 55 and the edge 57 is part of a Gothic arch shape in the transverse plane and is a circular arc of radius $R3$ struck from a point 58 on one side of the longitudinal plane of symmetry 60 of the track. The flank between the point 54 and the edge 56 is also part of a Gothic arch shape in the transverse plane and is a circular arc struck from a centre 59 on the other side of the plane 60 and has a radius $R4$. $R3$ and $R4$ are preferably equal but this is not essential. The angles subtended by the root portion at the centre 61 is the sum of the angles α and β and is preferably 80° , i.e. $\alpha = \beta = 40^\circ$. However α and β need not be equal but $\alpha + \beta$ should be between 70 and 90° . The track vertex line is indicated at 62.

It will thus be seen that the root of the track is a circular arc of radius $R2$ having a low numerical conformity 1.002. The flanks of the track between the points 54 and 55 and the edges are parts of a Gothic arch and are also arcuate and have a greater numerical conformity which may for example be 1.030.

It is not necessary that the flank portions of the track be circular arcs as described in relation to Figure 4, they could be parts of ellipses which would blend tangentially at the points 54 and 55 with the root arc. In this case the numerical conformity would vary along the ellipse but the average value should be as described above.

The advantages of this track design are as set out above. Thus the low numerical conformity in the track root spreads the ball load over a wide area thus reducing the stress on the track and the ball and the low numerical conformity also makes for a low rotational backlash as compared with a round track having a higher numerical conformity.

The higher numerical conformity in the flanks of the track protects the track edges from high stresses and reduces the sensitivity of the contact angle to variation in ball radial lash as defined above.

The new track form may be used either in the outer joint member or the inner joint member or both. If the new track form is only used in one of the members then the track form of the other member may be of any compatible form.

The invention has been described in relation to a fixed ball joint of the Rzeppa type. However the track form may also be used in cross-groove plunging joints and in plunging joints of the double-offset type in which the outer member has straight tracks.

The invention is more broadly applicable, however, and may be used in any torque-transmitting device of the kind specified in which balls roll along tracks in two co-operating members and are used to transmit torque from one member to the other via the tracks and the balls. Thus there are constant velocity joints of types other than those of the kind specified in which the new track form could be used. The track form could also be used, for example, in ball splines for the form of the splines.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate may, separately or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

Claims

1. A joint of the kind specified having a hybrid track form in the transverse plane as hereinbefore defined with a lower numerical conformity at the root portion of the track and with the flank portions of the track having a higher numerical conformity.
2. A joint of the kind specified in which in at least one of the inner and outer joint members the tracks have, in cross-section in the transverse plane as hereinbefore defined, a root portion formed as a circular arc with a relatively lower numerical conformity and flank portions on either side of the root portion and extending to or towards the edges of the tracks and which have a relatively higher numerical conformity.
3. A joint according to Claim 2 wherein the track form in the other joint member is of the form claimed in Claim 2 or is of any other compatible form.
4. A joint according to Claim 2 or Claim 3 wherein the angle subtended by the track root portion at the centre of the radius of the root portion arc is between 70° and 90° .
5. A joint according to Claims 4 wherein the root portion of the track subtends an angle of approximately 80° at the centre of the radius of the root portion, preferably 40° on either side of the longitudinal plane of symmetry of the track (as hereinbefore defined).
6. A joint according to any of Claims 2 to 5 wherein the track root portion has a numerical conformity within the range of 1 to 1.02.
7. A joint according to any of Claims 2 to 6 wherein the flanks of the track are formed by circular arcs struck from centres offset from the longitudinal plane of symmetry of the track and the higher numerical conformity of the flanks is between 1.005 and 1.09.

8. A joint according to Claim 7 wherein the numerical conformity of the flanks is between 1.02 and 1.03.
9. A joint according to any of Claims 2 to 6 wherein the flank portions of the track are formed by elliptical arcs and in which the average numerical conformity of the flank portions is between 1.005 and 1.09.
10. A joint of the kind specified substantially as hereinbefore described with reference to Figures 1 and 4 of the accompanying drawings.
11. A device of the kind specified having a hybrid track form in the transverse plane as hereinbefore defined with a lower numerical conformity at the root portion of the track and with the flank portions of the track having a higher numerical conformity.
12. A device according to Claim 11 wherein the angle subtended by the track root portion at the centre of the radius of the root portion arc is between 70° and 90° .
13. A device according to Claims 12 wherein the root portion of the track subtends an angle of approximately 80° at the centre of the radius of the root portion, preferably 40° on either side of the longitudinal plane of symmetry of the track (as hereinbefore defined).
14. A device according to any of Claims 11 to 13 wherein the track root portion has a numerical conformity within the range of 1 to 1.02.
15. A device according to any of Claims 11 to 14 wherein the flanks of the track are formed by circular arcs struck from centres offset from the longitudinal plane of symmetry of the track and the higher numerical conformity of the flanks is between 1.005 and 1.09.
16. A device according to Claim 15 wherein the numerical conformity of the flanks is between

1.02 and 1.03.

17. A device according to any of Claims 11 to 15 wherein the flank portions of the track are formed by elliptical arcs and in which the average numerical conformity of the flank portions is between 1.005 and 1.09.
18. A device according to any of Claims 11 to 17 in the form of a ball spline with the tracks forming the splines.
19. A device of the kind specified substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

Claims

1. A joint of the kind specified in which in at least one of the inner and outer joint members the tracks have, in cross-section in the transverse plane as hereinbefore defined, a root portion formed as a circular arc with a numerical conformity within the range of 1 to 1.02 and flank portions on either side of the root portion and extending to or towards the edges of the tracks and which have a numerical conformity between 1.005 and 1.09, the root portion having a lower numerical conformity than the flank portions, the angle subtended by the track root portion at the centre of the radius of the root portion arc being between 20° and 100° .
2. A joint according to Claim 1 wherein the track form in the other joint member is of the form claimed in Claim 1 or is of any other compatible form.
3. A joint according to Claims 4 wherein the root portion of the track subtends an angle of approximately 80° at the centre of the radius of the root portion, preferably 40° on either side of the longitudinal plane of symmetry of the track (as hereinbefore defined).
4. A joint according to any preceding claim wherein the flank portions are formed by circular arcs struck from centres offset from the longitudinal plane of symmetry of the track
5. A joint according to any preceding claim wherein the numerical conformity of the flank portions is between 1.02 and 1.03.
6. A joint according to any of Claims 1 to 3 wherein the flank portions of the track are formed by elliptical arcs and in which the average numerical conformity of the flank portions is between 1.005 and 1.09.
7. A joint of the kind specified substantially as hereinbefore described with reference to Figures 1 and 4 of the accompanying drawings.

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Application No: GB 9724368.7
Claims searched: 1 - 18

Examiner: C J Duff
Date of search: 27 July 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F2U

Int Cl (Ed.6): F16C, F16D

Other: On-line: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2050567 A (TOYOTA) See Fig 2	1, 11, 17
X	GB 1446159 (LÖHR & BROMKAMP) See Figs 4, 5	1, 11, 17
X	GB 0725687 (DAIMLER-BENZ) See Fig 1	11-13, 18
X	GB 0637718 (CULL) See Figs 3, 4	1, 11, 17
X	US 5288273 (KRUE) See Fig 8	1-5, 11-13

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

1/4

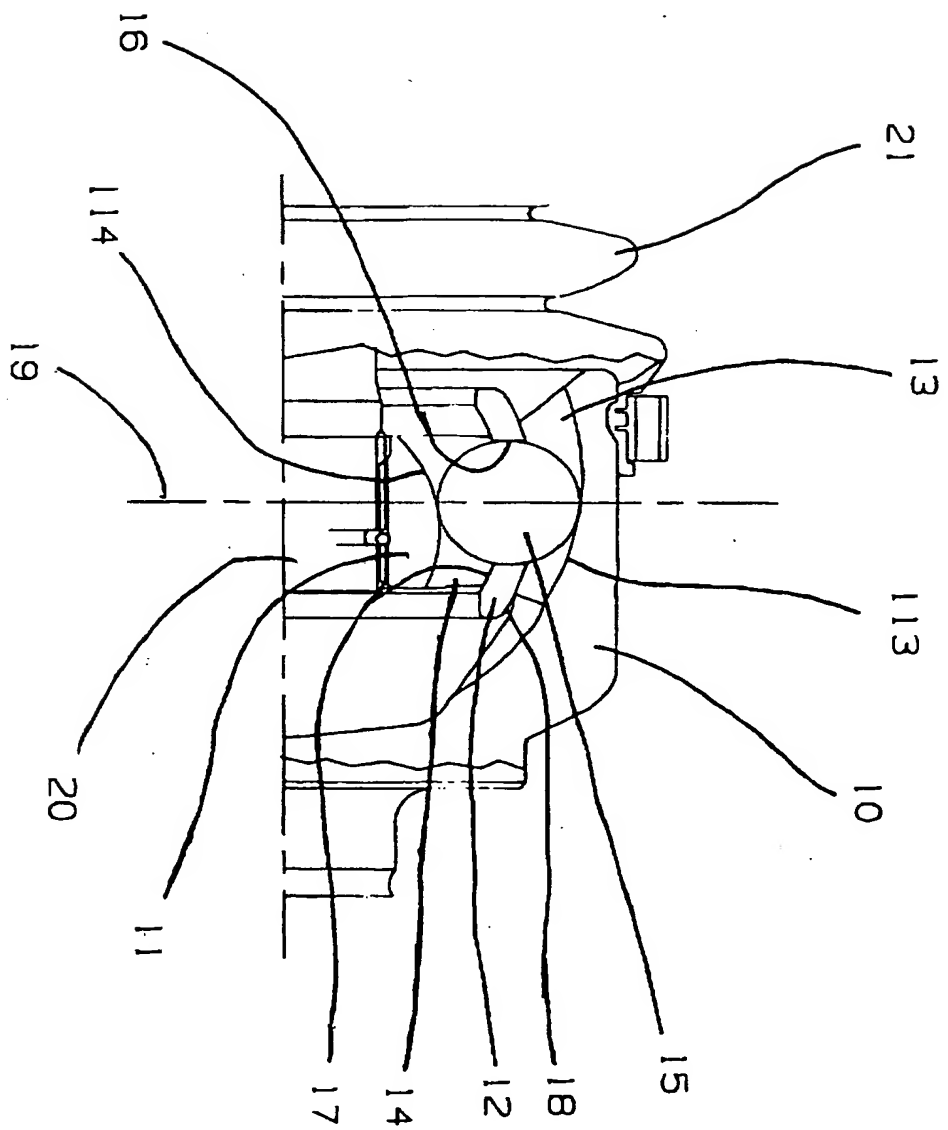


FIG. 1

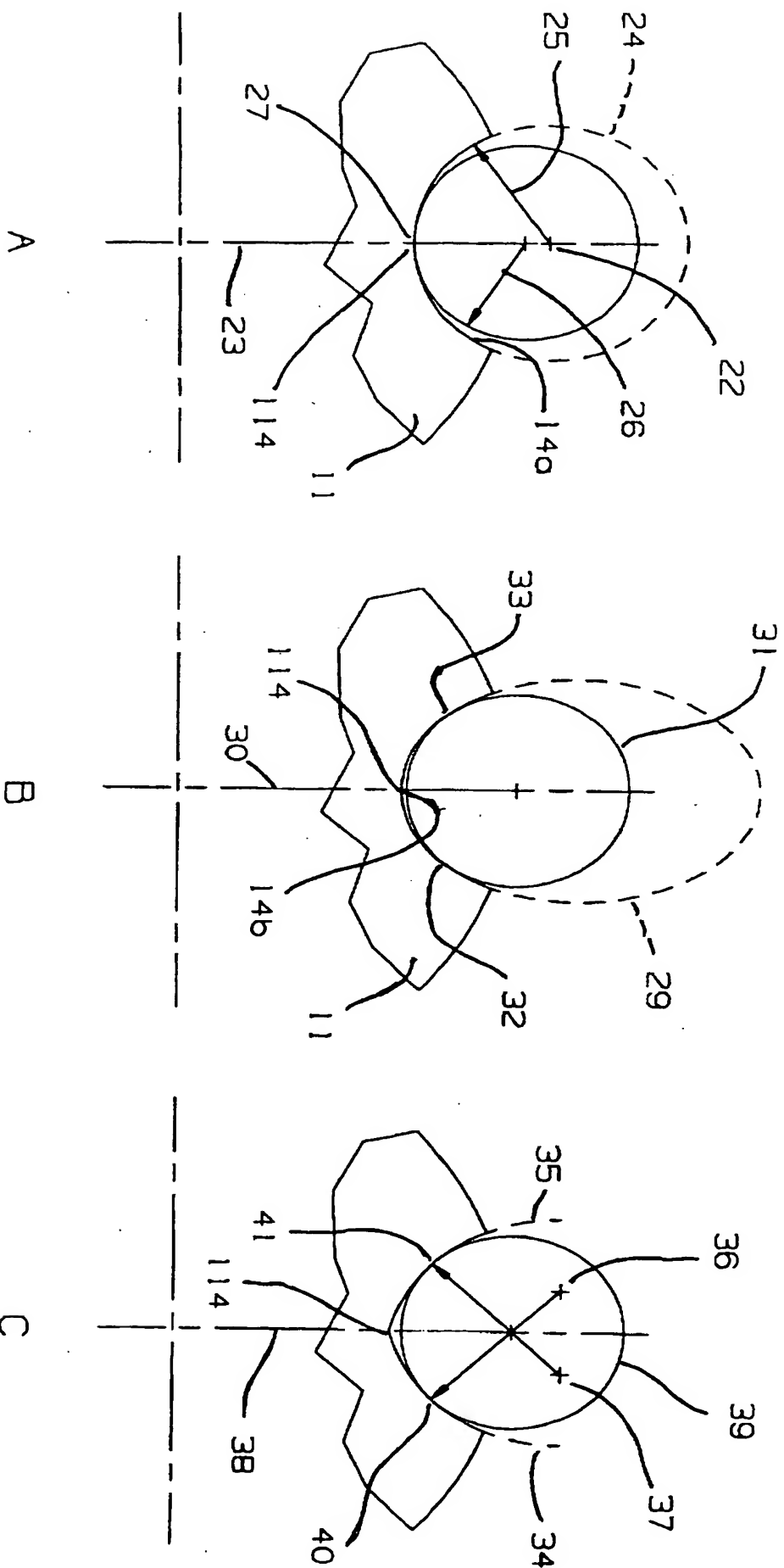


FIG. 2

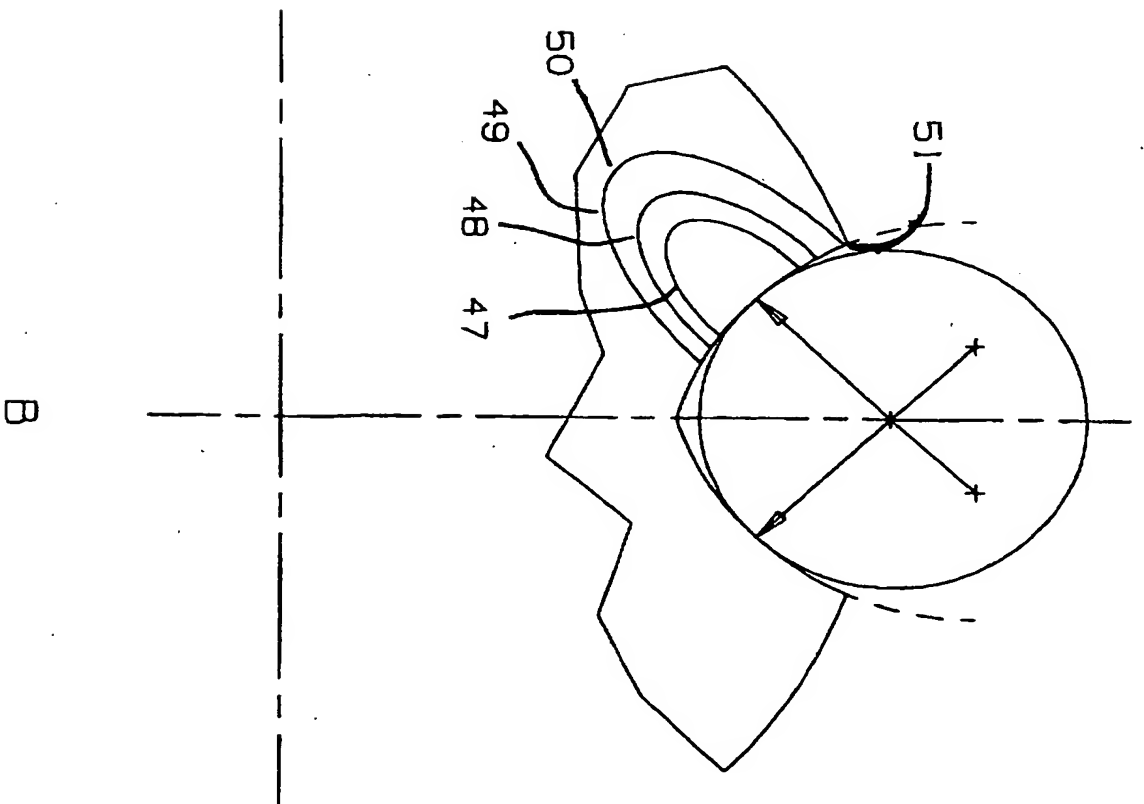
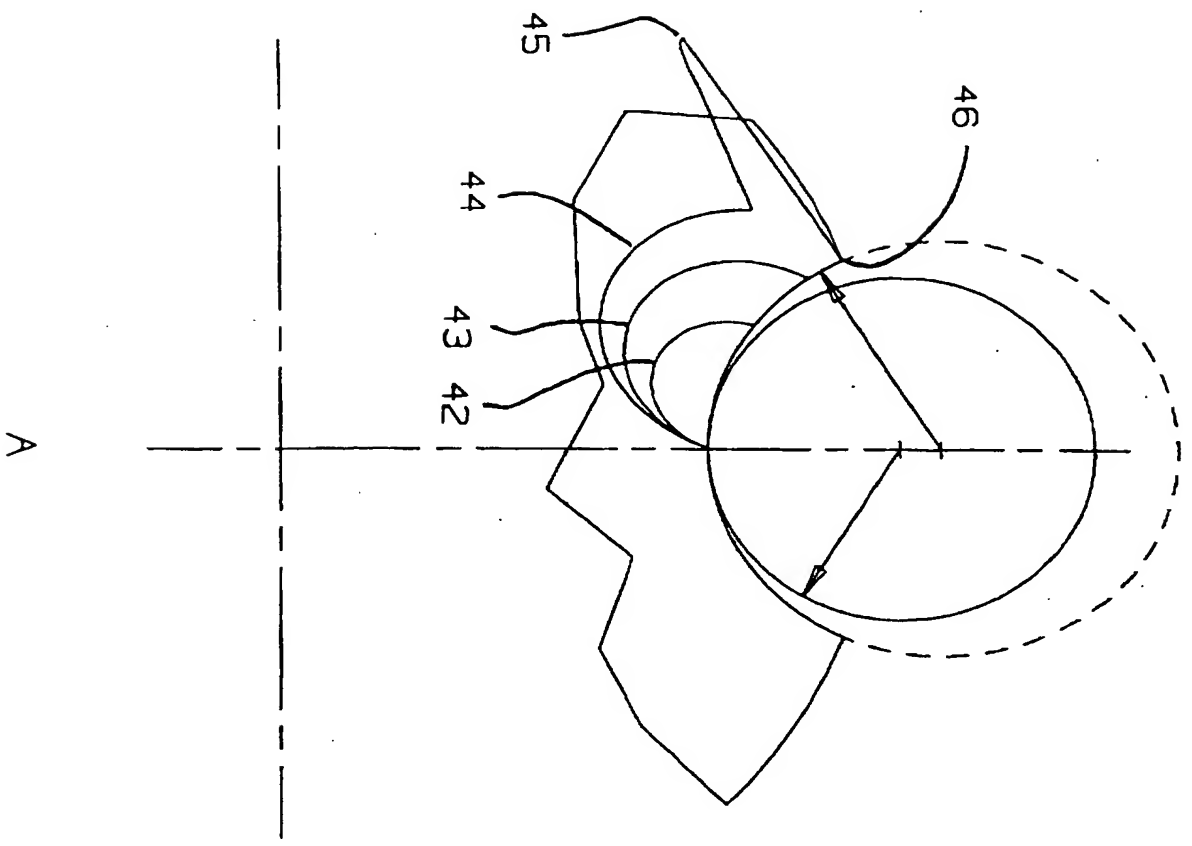


FIG. 3

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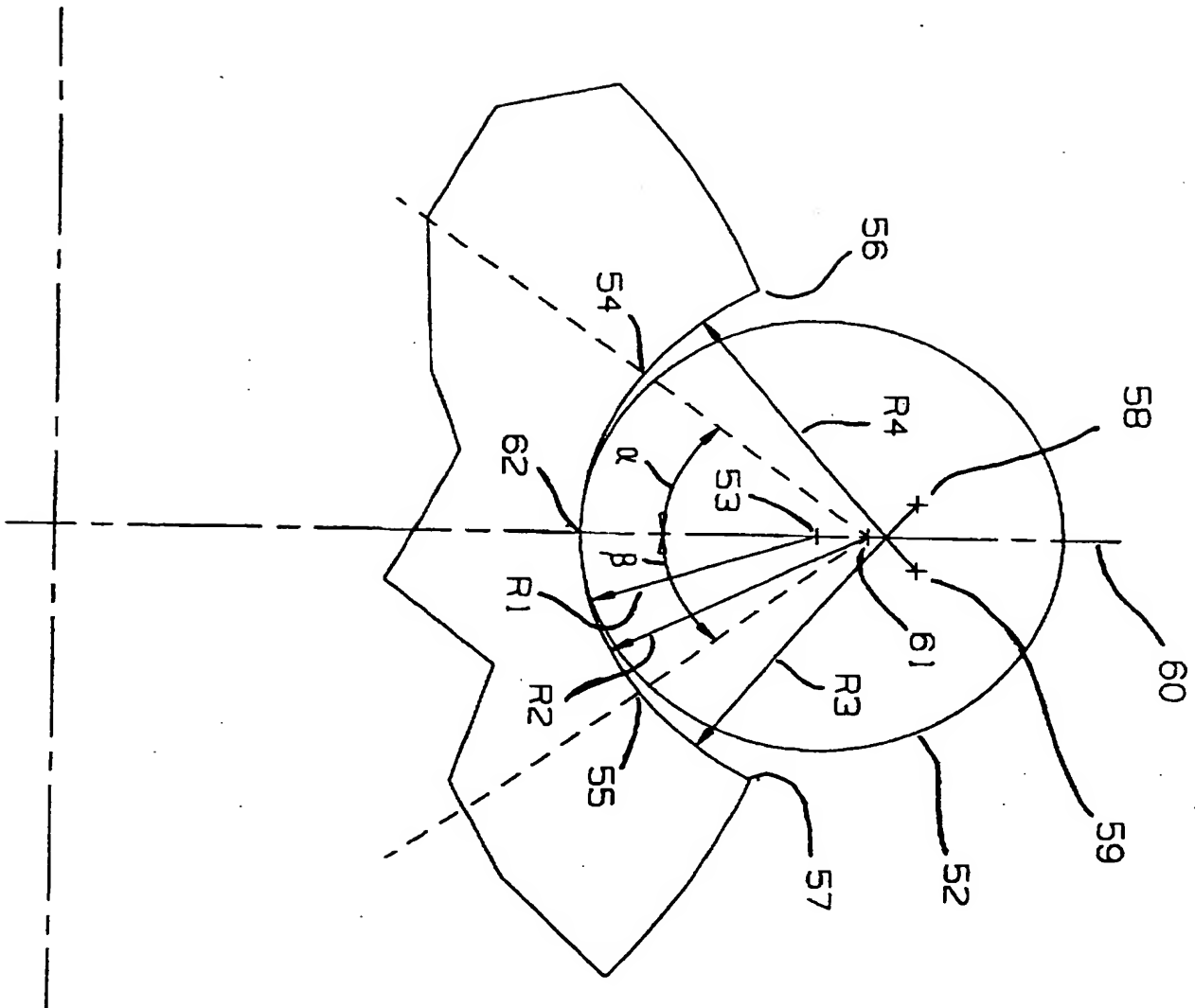


FIG. 4